U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE

HEARING CHARTER

Options for Hubble Science

February 2, 2005
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

1. Purpose and General Background

On Wednesday, February 2, the Committee on Science will hold a hearing to examine the options for the future of the Hubble Space Telescope.

Launched in 1990, the Hubble is, according to the National Academy of Sciences, "arguably the most powerful single optical astronomical facility ever built" and "a uniquely powerful observing platform" that has made "profound contributions" to the human understanding of the universe.

The Hubble was designed at a time (before the 1986 Challenger accident) when it was assumed that the Space Shuttle would be used regularly to launch and service satellites. As a result, the Hubble was launched by the Shuttle (rather than by an expendable rocket) and was designed to require periodic servicing by astronauts to remain aloft and functioning. Four missions have serviced the Hubble (including one that was not originally planned to correct a flaw in the Hubble's mirror). A fifth and final mission was scheduled for 2004 both to replace the batteries and gyroscopes the Hubble needs to continue to function and to add new scientific equipment. (That scientific equipment has already been built and is at the Goddard Space Flight Center in Maryland.) Without servicing, the Hubble will cease functioning as early as 2007 when the batteries run low; the exact timing is uncertain.

The demise of the Space Shuttle Columbia in February 2003 necessitated a change in the plans for the Hubble. At the very least, the loss of the Columbia meant a significant delay in Hubble servicing. (The Shuttle will not return to flight earlier than May 2005 and has a backlog of missions to construct and service the International Space Station (ISS).) But last January, NASA Administrator Sean O'Keefe ruled out any servicing mission, announcing that the Shuttle would no longer fly to destinations other than the ISS, citing safety concerns. That decision appeared to doom the Hubble.

But the Hubble was given a new lease on life, when, responding to a public outcry and pressure from Congress, NASA proposed last year to develop a robot to perform the necessary servicing. NASA also contracted with the National Academy of Sciences to review its decision.

In December, the Academy issued a report that took issue with every aspect of the NASA approach and recommended a Shuttle servicing mission. The Academy concluded that the likelihood of NASA's robotic plan succeeding was "remote." The Academy also found that a Shuttle sent to the Hubble faced risks similar to those faced by a Shuttle sent to the International Space Station. (NASA plans to send the Shuttle to the Space Station as many as 30 more times.)

Two additional studies funded by NASA, one performed internally and the other performed by the Aerospace Corporation, similarly concluded that a robotic mission to service the Hubble would not be ready in time to save the Hubble before its batteries died. (The Aerospace Corporation is a Federally Funded Research and Development Center that works primarily for the Air Force.)

The Aerospace Corporation additionally found that a new telescope built from the instruments NASA originally planned to install on the Hubble would provide the greatest value to NASA in terms of risk and cost. NASA has received a proposal, known has the Hubble Origins Probe, to build such a telescope from the instruments that already exist at Goddard and some additional new equipment.

Recent press reports have suggested that in its Fiscal Year (FY) 06 budget request, the Administration plans to cancel the robotic mission to service the Hubble, presumably because of the costs and uncertainty about success, once again dooming the telescope.

This hearing will help the Committee prepare for the debate over Hubble that will come to a head once the budget request is released Feb. 7. There are basically four options available with regard to the Hubble, each of which is discussed in greater detail later in this charter and in Attachment A:

- Do not service the telescope. The telescope will then cease to function as early as 2007. NASA does have other space telescopes in orbit and others are planned to be launched in 2011, but none has the same capabilities as Hubble.
- Send the Shuttle to service the telescope. Like any Shuttle mission, this would put astronauts at risk. It would also delay completion of the ISS.
- Send a robotic mission to service the telescope. The studies mentioned above have raised grave doubts as to whether this mission could be ready in time. The contractor designing the robot takes issue with those studies.
- Launch a new "platform" with the equipment that was designed to be added to the Hubble (this is sometimes called "rehosting") and perhaps include new equipment as well (the proposed "Hubble Origins Probe" or HOP). This would leave a gap in Hubble science, as the new platform would probably not be ready until after the Hubble stopped operating.

All of these options raise questions about cost as well as risk. But arguably (see below), they all cost in the range of $2 billion to complete. Any option, therefore, raises questions about whether Hubble servicing is a high enough priority to proceed even if it would take funds away from NASA's other science plans and its exploration mission.

Finally, regardless of which option is chosen, NASA will have to send a robot up to the Hubble around 2013 to deorbit it. Otherwise, the telescope will re-enter the Earth's atmosphere uncontrolled, potentially causing death and destruction upon landing. Designing a robot for deorbiting the Hubble is much less complicated than designing one to service the telescope, and much more time is available for the project as the Hubble is not expected to fall out of orbit for many years.

2. Overarching Questions

The Committee plans to explore the following overarching questions at the hearing:

1. How important are the contributions that would be expected from extending the life of the Hubble Space Telescope to the continued advancement of our understanding of the cosmos?

2. What are the comparative costs, strengths, and weaknesses of a shuttle servicing mission, a robotic servicing mission, and a mission to fly elements of a Hubble servicing mission rehosted on a new telescope?

3. Should either a Hubble servicing mission (whether by robot or by Shuttle) or a new Hubble-based telescope be a higher priority for funding than other astronomical programs at NASA?

3. Witnesses

Mr. Gary Pulliam is Vice President for Civil and Commercial Operations, Aerospace Corporation.

Dr. Lou Lanzerotti was Chair of the National Academy of Sciences study on the Hubble, known officially as the Committee on the Assessment of Options for Extending the Life of the Hubble Space Telescope. Dr. Lanzerotti is a professor of solar-terrestrial research at the New Jersey Institute of Technology and a consultant to Bell Labs and Lucent Technologies.

Dr. Steve Beckwith is Director of the Space Telescope Science Institute and a professor of physics and astronomy at the Johns Hopkins University. The Institute manages the Hubble Space Telescope on behalf of NASA.

Dr. Paul Cooper is Vice President and Deputy General Manager of MD Robotics, the company building the arm for the robotic servicing mission to repair the Hubble.

Dr. Colin Norman is a professor in the Department of Physics and Astronomy at the Johns Hopkins University, and the lead scientist on the proposal to build the Hubble Origins Probe.

Dr. Joseph Taylor is a Nobel Laureate and Distinguished Professor of Physics at Princeton University. In 2001 Dr. Taylor served as a co-chair of the National Academy of Science's "decadal survey," the document that recommended priorities for astronomy and astrophysics missions in this decade. The survey is prepared by the Academy's Astronomy and Astrophysics Survey Committee. Dr. Taylor also served on the Academy's Hubble Committee that was chaired by Dr. Lanzerotti.

4. Issues

These are some of the questions that need to be evaluated in deciding what to do about the Hubble:

- **How important is it to have the Hubble Telescope's life extended and its capabilities enhanced?** Every ten years astronomers come together under the aegis of the National Academy of Sciences to survey their field and develop a list of priority research questions to be pursued and funded by NASA (the "decadal survey"). The most recent decadal survey, released in 2001, assumed that Hubble would be serviced in 2004 and be available to scientists until around 2010. Some of the priority projects were expected to work in conjunction with Hubble. It is unclear how the priorities in the decadal survey would shift if Hubble servicing were cancelled, of if servicing (by Shuttle or robot) were to take funds from other planned science missions. It is also unclear where a project like HOP would rank among the options for astronomy.

- **How much time does NASA have to send a mission to the Hubble before it can no longer be rescued?** When the Hubble's batteries will run too low to protect the telescope from the frigid temperatures of space cannot be predicted precisely. The National Academy of Sciences' Hubble report projected that the batteries would most likely run low by May 2009. The Aerospace Corporation reached similar conclusions. The ability of the Hubble to perform science is likely to erode sooner, mostly likely in April 2008, according the Academy. NASA could extend the life of the batteries somewhat by putting the telescope into a "dormant" mode in anticipation of a servicing mission. Any servicing mission that arrived after the batteries ran down would be pointless.

- **How much time would a robotic mission to service Hubble take to develop?** Predicting how long a complex space mission will take to develop is fraught with uncertainty. The Aerospace Corporation estimated that a mission to service the Hubble robotically would not be ready to launch for at least 65 months, or 5.4 years, too late to rescue the Hubble telescope. NASA claims, however, that its robotic mission will be ready in only 39 months, or 3.25 years.

The crux of the dispute is the question of how novel a Hubble robotic mission would be. NASA and MD Robotics point out that the "arm" the robot would use has already been developed and used by the Shuttle. Skeptics argue that the "arm" has not been used for an analogous mission and rendezvousing with the Hubble gently enough to avoid damaging it will be tricky.

- **How much time would a Shuttle mission to service Hubble take to prepare for?** NASA has estimated that it would take 31 months to prepare a Shuttle mission to Hubble, which includes crew training and having a back-up Shuttle available for any rescue mission (a new approach in the wake of the Columbia accident). The Academy concluded that the latest a Shuttle mission to Hubble could launch and still save the telescope was May 2009.

- **Where would the funding come from to pay for a servicing mission to Hubble?** Past Hubble servicing missions have been paid out of the Shuttle program's budget. Since the last Shuttle was sent to the Hubble in 2002, NASA has adopted a new bookkeeping method in which each program must pay for activities that benefit it, even if those activities are carried out by another program. Under this "full cost accounting" methodology, NASA's Science Directorate might be expected to pay for all or part of a Shuttle mission to service the Hubble. In the meantime, the funding for the robotic servicing mission – contracts have already been let to design the robot – is being split between NASA's Science Directorate, in which the Hubble program resides, and the Exploration Directorate, which hopes to benefit from the robotic technology that the Hubble mission would develop. (The Exploration Directorate is charged with developing new technology for the President's proposal to return humans to the moon.) If money for Hubble servicing started eating into other planned science projects, support for a Hubble servicing mission in the science community might erode.

- **How much would a servicing mission to Hubble cost? Which mission provides the highest value?** According to the Aerospace Corporation, the total cost of a robotic servicing mission would be roughly $2 billion. NASA estimated the cost at $1.3 billion. The initial contracts for the robotic mission have come in at less than Aerospace had estimated, but some of those contracts allow for cost escalation as the project continues.

  According to NASA, the cost of a Shuttle servicing mission to Hubble would cost a similar amount, $2.2 billion. This is basically NASA's estimate of the cost of any Shuttle flight, not an estimate of costs unique to a Hubble mission. Aerospace did not conduct an independent estimate of the cost of a Shuttle servicing mission. The Government Accountability Office has said it cannot verify NASA's estimates of Shuttle costs.

The Aerospace Corporation found that a simple "rehosting" option – sending up just the instruments already built to be added to Hubble – would also cost about the same amount, roughly $2 billion. Proponents of HOP, which would include additional equipment, claim that their proposal would cost about $1.5 billion.

The Omnibus Appropriations Bill for FY 05 that the President signed in December specifically included $291 million to begin work on the robotic servicing mission, which would be expected to launch in FY 07. According to its latest Operating Plan, NASA plans to allocate $175 million to the project in FY05.

- **Would a Shuttle flight to Hubble be riskier than one to the International Space Station?** The NASA Administrator has said that his decision not to send Shuttle to the Hubble was based in large part on his belief that astronauts would face a greater risk on such a mission compared to a mission to the International Space Station. NASA has never provided any data to back up that assertion but it appears to be based on the assumption that the ISS can act as a "safe haven" in the event that a problem with the Shuttle is discovered during a mission. (Shuttles sent to the Hubble cannot reach the ISS.) Some critics have charged that the Shuttle mission to Hubble was scrapped solely to accelerate the construction of the ISS. The National Academy of Sciences found that the difference in risk between a single mission to Hubble and a mission to the Space Station is "very small." Furthermore, the Academy pointed out that NASA plans to send the Shuttle to the Space Station 25 to 30 more times. The probability of another accident occurring in 30 flights can be calculated to be greater than 40 percent if the past accident rate of the Shuttle (2 in 113 flights) is used to predict future reliability. In addition, some experts have argued that proposed missions to the Moon and Mars are likely to pose much greater risks to astronauts than a Shuttle mission to the Hubble.

5. Background

The Hubble Space Telescope:

The Hubble Space Telescope (HST) was launched from the Space Shuttle *Discovery* in 1990 and has operated continuously in orbit for the past 14 years. The Hubble was originally designed for a 15-year mission, but until recently NASA intended to extend its operations through 2010. The telescope was designed to be serviced by astronauts, and a series of four shuttle servicing missions, the last flown in 2002, have replaced nearly all of the key components except the original telescope mirrors and support structures. Three of the four servicing missions added major new instruments, boosting the telescope's observing capabilities.

HST is one of the most powerful optical astronomical telescopes ever built. It was designed to make observations in the visible, ultraviolet, and near-infrared wavelength portions of the spectrum, and its orbit above the Earth's blurring atmosphere provides an unobscured and undistorted view of the Universe.

In its report, the Academy cited as the Hubble's primary scientific achievements:

- Direct observation of the universe as it existed 12 billion years ago;
- Measurements that helped to establish the size and age of the universe;
- Discovery of massive black holes at the center of many galaxies;
- Key evidence that the expansion of the universe is accelerating, which can be explained only by the existence of a fundamentally new type of energy and therefore new physics; and
- Observation of proto-solar systems in the process of formation.

Prior to the *Columbia* shuttle accident, NASA had scheduled a servicing mission (SM-4) slated for 2004 to replace the batteries, gyroscopes and fine guidance sensors, all of which are showing signs of failure. SM-4 was also to install new thermal blankets and two new science instruments, the Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS). The Shuttle would also have raised Hubble's orbit. After performing these repairs and new instruments, NASA expected the Hubble would continue to operate for another three to five years.

Hubble is not the only space-based astronomical observatory, though it is only one that operates in optical wavelengths. The Spitzer Space Telescope, which NASA launched in August 2003, has a 2.5-year mission and is designed to observe in the infrared portion of the spectrum. NASA launched the Chandra X-ray Observatory in July 1999. While Chandra had only a five-year mission, it has been operating past its planned lifetime and continues to perform well today. The next telescope mission, scheduled for launch in 2011, is the James Webb Space Telescope (JWST). It will observe in the infrared portion of the spectrum using the largest mirror (6 meter diameter) ever flown in space. (As all of these telescopes were designed after 1986, none relies on the Shuttle for launch or requires servicing.) Scientists greatly value the ability to do complementary observations using any or all of these active telescopes, peering at the same target at the same time. When the Hubble operations cease, there will be no other space-based optical telescope available.

The Columbia Accident Investigation Board:

Following the *Columbia* accident in February 2003, NASA appointed the Columbia Accident Investigation Board (CAIB) to investigate the accident. The CAIB's report included 15 Return To Flight (RTF) recommendations that it said should be completed prior to NASA resuming Shuttle flights, and an additional 14 recommendations to assure continued safe operation.

At times, NASA has argued that its decision to cancel the Shuttle mission to Hubble was the only option available in light of the CAIB report. And the CAIB did make some distinctions between missions to the ISS and other missions.

The clearest example is in its recommendation 6.4-1, which states in part, "For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios." NASA has not developed that capability. But at the request of Senator Barbara Mikulski of Maryland, Admiral Harold Gehman, the chairman of the CAIB, clarified the recommendation.

In a March 2004 letter, Gehman said that risk to the Shuttle needed to be reviewed in light of all of CAIB's recommendations, not just a single recommendation, and he said the wording of the specific recommendation for non-Station missions meant "do the best you can." He said non-ISS missions "may be slightly more risky" than missions to the ISS. Admiral Gehman said that the CAIB had taken no position on the feasibility of a Hubble mission and that all Shuttle missions posed risks. He concluded, "I suggest only a deep and rich study of the entire gain/risk equation can answer the question of whether an extension of the life of the wonderful Hubble telescope is worth the risks involved, and that is beyond the scope of this letter." Gehman's response was one impetus for the Academy study.

The Academy Report:

NASA commissioned the National Academy of Sciences study in the spring of 2004, in response to Congressional requests and shortly after initiating efforts to study the feasibility of a robotic servicing mission. NASA asked the National Academy of Sciences to assess "the viability of a space shuttle servicing mission" that would satisfy all of the CAIB's and NASA's own additional safety recommendations. The Academy was also asked to consider the viability of a robotic servicing mission.

The Academy's panel, *The Committee on the Assessment of Options for Extending the Life of the Hubble Space Telescope* (the full charter and a list of committee members are attached), made three recommendations:

1. That NASA should commit to a servicing mission to the Hubble Space Telescope that accomplishes the objectives of the originally planned SM-4 mission.
2. That NASA should send the Shuttle to service the Hubble as soon as possible.
3. That a robotic mission approach should be pursued solely to de-orbit Hubble after its mission is completed.

The Academy expressed strong doubts about the likely success of NASA's plans for a robotic servicing mission, stating: "Based on extensive analysis, the committee concluded that the very aggressive schedule for development of a viable robotic servicing mission, the commitment to development of individual elements with incomplete systems engineering, the complexity of the mission design, the current low level of technology maturity, the magnitude of the risk-reduction efforts required, and the inability of a robotic servicing mission to respond to unforeseen failures that may well occur on Hubble

between now and the mission, together make it unlikely that NASA will be able to extend the service life of HST through robotic servicing."

Robotics experts at NASA and its contractors dispute the Academy's characterization of the overall level of technical maturity of the robotic mission's components. For instance, they argue that the Shuttle's robotic arm (on which the robotic arm for the servicing mission will be based) has suffered no mission failures in 25 years of use. They also contend that the Academy's assessment of robotics risk is out of date since it is based on information and site visits that occurred during late spring/early summer 2004. Developments since then, they say, have eliminated many of the risks.

In recommending that NASA conduct a servicing mission with the Shuttle, the Academy suggested that to minimize risk, NASA should prepare to use two shuttles – one to fly to Hubble, and the second to sit at the ready on an adjacent launch facility to be used as a rescue vehicle should the first suffer damage that precludes a safe return. This was based on a rescue scenario outlined in the CAIB report.

NASA argues that this proposal is not feasible because it would increase the cost of the mission, further disrupt the schedule for completing the International Space Station, and put additional crew at risk as the rescue mission would be unprecedented. Any rescue mission would have to be launched quickly (within 17-30 days, depending on how much emergency power was available on the Shuttle). Astronauts would have to be transferred in space from one shuttle to another, a task NASA views as without precedent. However, the Academy report found that spacewalks "for transferring the crew from a damaged vehicle on a shuttle HST flight, although complex, are well within the experience base of the shuttle program."

The Aerospace Corporation Report:

The Academy panel relied heavily on a study produced by the Aerospace Corporation that analyzed a variety of alternative methods for extending the life of Hubble. The report was requested, and paid for, by NASA as an analysis of alternatives (AoA).

Aerospace used a "blank sheet of paper" approach that considered generic options rather than any specific pending proposal. As a result, it did not review the specific robotics work underway for the Hubble mission, which was only in an early stage when the Aerospace study was done in any event. (The Aerospace Report was completed in August, 2004.) Aerospace also did not review NASA's cost or schedule estimates for the Shuttle, but simply accepted them as a baseline.

Aerospace was not charged with recommending a specific alternative, but only with ranking their relative costs and benefits. Key findings of the Aerospace study include:

- Robotic servicing alternatives, based on estimated development schedules, are susceptible to arriving too late when Hubble is no longer in a serviceable state.

Furthermore, they undertake unprecedented servicing operations and are subject to an aging observatory that may fail for some other reason following servicing.

- Rehost alternatives are lower risk with similar cost to the robotic servicing missions, but may result in a two- to seven-year science gap.
- SM-4 has costs in the same range as the rehost and robotic servicing alternatives, has higher probability of mission success than the robotic servicing missions, and does not suffer from the gap in science associated with rehost alternatives.
- Other means to perform astronaut servicing with reduced risk such as launching a safe haven or relocating Hubble to the vicinity of the International Space Station are more costly and take longer to develop than SM-4.

Aerospace Analysis of Alternatives – Summary of HST Servicing Study Results

	Life Cycle Cost (FY04 $B)	Nominal Development Time (years)	Development Risk	Mission Risk
Shuttle Servicing Mission SM-4	$2.2	2.6	Medium	Medium
Robotic Servicing Mission	$2.0	5.4	High	High
De-orbit Mission (no life extension)	$0.4	4.2	Low	Low
Rehosting SM-4 on a Free Flyer	$2.0	8.4	Low	Low

(Aerospace Corporation defines "Development Risk" for a servicing mission as the risk that the mission can be developed in time to reach the Hubble before irreparable damage occurs. Aerospace defines "Mission Risk" for a servicing mission as the risk that every element of the mission will succeed as planned and the telescope will continue to operate for another 3 years after being serviced.)

6. Recent Developments

NASA continues to work on a robotic servicing mission, for which the FY05 Omnibus Appropriations bill provided $291 million. Of this amount, NASA plans to spend $175 million through Preliminary Design Review, scheduled for late March – the stage at which a decision is normally made as to whether to carry on with a project. Another

critical stage in the program's development, the Critical Design Review, is tentatively scheduled for this September.

NASA recently let contracts valued at $330 million to Lockheed Martin to begin development work on a spacecraft that could be used for either a robotic servicing mission or a comparatively simple robotic de-orbiting mission. A contract valued at $153 million was let to MD Robotics, a subsidiary of the Canadian firm MacDonald Dettwiler, to develop the robotic arm that would perform any servicing. The company built the existing Shuttle robotic arm.

7. Questions Asked of the Witnesses

Witnesses invited to appear before the Committee were asked to address the following questions in their testimony:

Mr. Gary Pulliam

1. Please summarize the findings of your report to NASA analyzing the agency's alternatives in servicing the Hubble Space Telescope. In particular please explain the comparative strengths and weaknesses of a shuttle servicing mission, a robotic servicing mission, and a mission to fly elements of a Hubble serving mission rehosted on a new telescope.
2. How confident are you of your cost estimates for each of the options?

Dr. Lou Lanzerotti, Chairman

Please explain the findings and recommendations of your panel's assessment of options for extending the life of the Hubble Space Telescope with a particular emphasis on the following questions:

1. What is the telescope's contribution to science and what would be lost if the telescope were not to be serviced and no replacement telescope launched?
2. What are the comparative costs, strengths, and weaknesses of a shuttle servicing mission, a robotic servicing mission, and a mission to fly elements of a Hubble servicing mission rehosted on a new telescope?
3. How disruptive to science would it be if Hubble's new instruments were to be unavailable for a number of years? Would any of your panel's findings and recommendations change if NASA were unable to launch a Shuttle servicing mission in time to prevent a "gap" in Hubble science?
4. How would you personally, or on behalf of the Committee, evaluate a free flyer (rehosting) instead of a servicing mission?

Dr. Steve Beckwith

1. How important are the contributions that would be expected from extending the life of the Hubble Space Telescope when compared to advancements expected

from other astronomical programs at NASA to be launched in the next decade, such as the James Webb Space Telescope?
2. What are the comparative strengths and weaknesses of a shuttle servicing mission, a robotic servicing mission, and a mission to fly elements of a Hubble servicing mission rehosted on a new telescope?
3. Should either a Hubble servicing mission (whether by robot or by Shuttle) or a new telescope as the Hubble Origins Probe be a higher priority for funding than other astronomical programs at NASA?

Dr. Paul Cooper, General Manager

Please describe the robotic mission to service the Hubble Space Telescope that you are helping to develop for NASA with particular emphasis on the following questions:

1. To what extent do you agree or disagree with the assessment by the Aerospace Corporation of a robotic servicing mission?
2. What are the costs, strengths, and weaknesses of the robotic servicing mission, compared to a shuttle servicing mission and a mission to fly elements of a Hubble servicing mission rehosted on a new telescope?

Dr. Colin Norman

Please briefly describe your proposal for NASA to build and fly a new telescope called the Hubble Origins Probe with particular emphasis on the following questions:

1. How, if at all, does your proposal differ from those analyzed by the Aerospace Corporation?
2. What contributions could your proposed telescope make to science compared to those that could be made by the Hubble if it were serviced by either the Shuttle or a robotic servicing mission?
3. What are the comparative costs, strengths, and weaknesses of your proposal, a shuttle servicing mission and a robotic servicing mission?

Dr. Joseph H. Taylor, Jr.

1. To what extent, and in what ways, was the Decadal Survey premised on the Hubble Space Telescope having additional instruments that were to be added by a servicing mission? Would the loss of the Hubble cause you to entirely rethink your priorities? Would that change if the *Hubble Origins Probe* or a similar rehost mission is launched?
2. How important are the contributions that would be expected from extending the life of the Hubble Space Telescope when compared to advancements expected from other astronomical programs at NASA to be launched in the next decade, such as the James Webb Space Telescope?
3. Should either a Hubble servicing mission (whether by robot or by Shuttle) or a new telescope as the Hubble Origins Probe be a higher priority for funding than other astronomical programs at NASA?